

## DESCRIPTION

## Cleaning Gas for Semiconductor Production Equipment

## 5 CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on the provisions of 35 U.S.C. Article 111(a) with claiming the benefit of filing dates of U.S. provisional application Serial No. 60/230,811 filed on September 7, 2000 and U.S. 10 provisional application Serial No. 60/261,265 filed on December 27, 2000 under the provisions of 35 U.S.C. 111(b), pursuant to 35 U.S.C. Article 119(e) (1).

## TECHNICAL FIELD

15 The present invention relates a cleaning gas for semiconductor production equipment. Specifically, the present invention relates to a cleaning gas for removing unnecessary deposits in film-forming equipment or etching equipment for the production of a semiconductor or a TFT 20 liquid crystal device, which are accumulated at the film formation or etching of silicon, silicon nitride, silicon oxide, tungsten and the like, to a cleaning method using the cleaning gas, and also to a method for producing a semiconductor device including a cleaning step using the 25 cleaning gas.

## BACKGROUND ART

In the film-forming equipment or etching equipment for the production of a semiconductor or a TFT liquid 30 crystal device, the deposits accumulated at the film-formation or etching of silicon, silicon nitride, silicon oxide, tungsten and the like cause generation of particles and hinder the production of good film,

therefore, these deposits must be removed on occasion.

Heretofore, the deposits in semiconductor production equipment are removed by a method of etching the deposits using a plasma excited from a fluorine-type etching gas such as  $\text{NF}_3$ ,  $\text{CF}_4$  and  $\text{C}_2\text{F}_6$ . However, the method of using  $\text{NF}_3$  has a problem in that the  $\text{NF}_3$  is expensive, and the method of using perfluorocarbon such as  $\text{CF}_4$  and  $\text{C}_2\text{F}_6$  has a problem in that the etching rate is low and the cleaning efficiency is low.

JP-A-8-60368 (the term "JP-A" as used herein means an "unexamined published Japanese patent application") describes a method of using a cleaning gas where at least one gas of  $\text{F}_2$ ,  $\text{ClF}_3$ ,  $\text{BrF}_3$  and  $\text{BrF}_5$  is mixed in an amount of 1 to 50 vol% with  $\text{CF}_4$  or  $\text{C}_2\text{F}_6$ . Also, JP-A-10-72672 describes a method of using  $\text{F}_2$  diluted with an inert carrier gas as the cleaning gas. However, these methods have a problem in that the etching rate is lower and the cleaning efficiency is lower than the method of using  $\text{NF}_3$  as a cleaning gas.

JP-A-3-146681 describes a mixed gas composition for cleaning, where at least one gas of  $\text{F}_2$ ,  $\text{Cl}_2$  and a halogen fluoride is mixed in an amount of 0.05 to 20 vol% with  $\text{NF}_3$  to improve the etching rate. Also, a plasmaless cleaning method using a halogen fluoride such as  $\text{ClF}_3$  as the cleaning gas is known. However, the halogen fluoride is very expensive and moreover, extremely highly reactive, therefore, despite the excellent cleaning efficiency, there is a problem in that the greatest possible care is necessary for the handling. Furthermore, the halogen fluoride may damage the equipment material inside the semiconductor production equipment and therefore, its use is disadvantageously limited only to some devices such as CVD device.

That is, conventionally known cleaning gases have the following problems:

(1) the gases having high cleaning efficiency are expensive; and

5 (2) the gases cannot be used except for some devices.

Inexpensive cleaning gases have a problem in that both the etching rate and the cleaning efficiency are low.

The present invention has been made under these  
10 circumstances. Accordingly, one of the objects of the present invention is to provide a cleaning gas and a cleaning method, which ensure high etching rate, high cleaning efficiency and excellent cost performance. One  
15 of the objects of the present invention is to provide a method for producing a semiconductor device.

#### DISCLOSURE OF THE INVENTION

As a result of extensive investigations to solve the  
20 above-described problems, the present inventors have found that a cleaning gas obtained by mixing  $\text{SF}_6$  and one or both of  $\text{F}_2$  and  $\text{NF}_3$  with an inert gas at a specific ratio is remarkably improved in the etching rate and elevated in the cleaning efficiency. Moreover, the  
25 present inventors have found that the cleaning efficiency is further improved by using the cleaning gas with an oxygen-containing gas contained therein in a specific ratio.

The present invention relates to a cleaning gas for  
30 cleaning semiconductor production equipment as described in (1) to (22) below, to a cleaning method as described in (23) to (32) below, and to a method for producing a semiconductor device, described in (33) and (36) below.

(1) A cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits in the equipment, comprising an inert gas and at least two gases selected from the group consisting of  $\text{SF}_6$ ,  $\text{F}_2$ , and  $\text{NF}_3$  excluding the combination of  $\text{F}_2$  and  $\text{NF}_3$  alone.

(2) The cleaning gas for semiconductor production equipment as described in (1) above, comprising  $\text{SF}_6$ ,  $\text{F}_2$ , and an inert gas.

(3) The cleaning gas for semiconductor production equipment as described in (1) above, comprising  $\text{SF}_6$ ,  $\text{NF}_3$ , and an inert gas.

(4) The cleaning gas for semiconductor production equipment as described in (1) above, comprising  $\text{SF}_6$ ,  $\text{F}_2$ ,  $\text{NF}_3$ , and an inert gas.

(5) The cleaning gas for semiconductor production equipment as described in any one of (1) to (4) above, wherein the inert gas is at least one selected from the group consisting of He, Ne, Ar, Xe, Kr and  $\text{N}_2$ .

(6) The cleaning gas for semiconductor production equipment as described in (5) above, wherein the inert gas is at least one selected from the group consisting of He, Ar, and  $\text{N}_2$ .

(7) The cleaning gas for semiconductor production equipment as described in (1) above, wherein  $\text{F}_2$  and/or  $\text{NF}_3$  is from 0.01 to 5 and the inert gas is from 0.01 to 500 in terms of the volume ratio assuming that  $\text{SF}_6$  is 1.

(8) The cleaning gas for semiconductor production equipment as described in (7) above, wherein  $\text{F}_2$  and/or  $\text{NF}_3$  is from 0.1 to 1.5 and the inert gas is from 0.1 to 30 in terms of the volume ratio assuming that  $\text{SF}_6$  is 1.

(9) The cleaning gas for semiconductor production equipment as described in (1) above, which contains at least one gas selected from the group consisting of

perfluorocarbon, hydrofluorocarbon, perfluoroether and hydrofluoroether.

(10) The cleaning gas for semiconductor production equipment as described in (9) above, wherein the  
5 perfluorocarbon and hydrofluorocarbon each has from 1 to 4 carbon atoms and the perfluoroether and hydrofluoroether each has from 2 to 4 carbon atoms.

(11) A cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits  
10 in the equipment, comprising an oxygen-containing gas, an inert gas and at least two gases selected from the group consisting of  $\text{SF}_6$ ,  $\text{F}_2$ , and  $\text{NF}_3$  excluding the combination of  $\text{F}_2$  and  $\text{NF}_3$  alone.

(12) The cleaning gas for semiconductor production equipment as described in (11) above, comprising an inert  
15 gas, an oxygen-containing gas,  $\text{SF}_6$ , and  $\text{F}_2$ .

(13) The cleaning gas for semiconductor production equipment as described in (11) above, comprising an oxygen-containing gas, an inert gas,  $\text{SF}_6$ , and  $\text{NF}_3$ .

(14) The cleaning gas for semiconductor production equipment as described in (11) above, comprising an  
20 oxygen-containing gas, an inert gas,  $\text{SF}_6$ ,  $\text{F}_2$  and  $\text{NF}_3$ .

(15) The cleaning gas for semiconductor production equipment as described in any one of (11) to (14) above,  
25 wherein the oxygen-containing gas is at least one selected from the group consisting of  $\text{O}_2$ ,  $\text{O}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{CO}$  and  $\text{CO}_2$ .

(16) The cleaning gas for semiconductor production equipment as described in (15) above, wherein the oxygen-  
30 containing gas is  $\text{O}_2$  and/or  $\text{N}_2\text{O}$ .

(17) The cleaning gas for semiconductor production equipment as described in any one of (11) to (14) above, wherein the inert gas is at least one selected from the

group consisting of He, Ne, Ar, Xe, Kr and N<sub>2</sub>.

(18) The cleaning gas for semiconductor production equipment as described in (17) above, wherein the inert gas is at least one selected from the group consisting of He, Ar, and N<sub>2</sub>.

(19) The cleaning gas for semiconductor production equipment as described in (11) above, wherein F<sub>2</sub> and/or NF<sub>3</sub> is from 0.01 to 5, the oxygen-containing gas is from 0.01 to 5 and the inert gas is from 0.01 to 500 in terms of the volume ratio assuming that SF<sub>6</sub> is 1.

(20) The cleaning gas for semiconductor production equipment as described in (19) above, wherein F<sub>2</sub> and/or NF<sub>3</sub> is from 0.1 to 1.5, the oxygen-containing gas is from 0.1 to 1.5 and the inert gas is from 0.1 to 30 in terms of the volume ratio assuming that SF<sub>6</sub> is 1.

(21) The cleaning gas for semiconductor production equipment as described in (11) above, which contains at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon, perfluoroether and hydrofluoroether.

(22) The cleaning gas for semiconductor production equipment as described in (21) above, wherein the perfluorocarbon and hydrofluorocarbon each has from 1 to 4 carbon atoms and the perfluoroether and hydrofluoroether each has from 2 to 4 carbon atoms.

(23) A method for cleaning semiconductor production equipment, comprising use of the cleaning gas described in any one of (1) to (10) above.

(24) The method for cleaning semiconductor production equipment as described in (23) above, wherein the cleaning gas described in any one of (1) to (10) above is excited to produce plasma and the deposits in the semiconductor production equipment are removed in the

plasma.

(25) The method for cleaning semiconductor production equipment as described in (24) above, wherein the excitation source for the plasma is a microwave.

5 (26) The method for cleaning semiconductor production equipment as described in any one of (23) to (25) above, wherein the cleaning gas described in any one of (1) to (10) above is used at a temperature range of 50 to 500°C.

10 (27) The method for cleaning semiconductor production equipment as described in (23) above, wherein the cleaning gas described in any one of (1) to (10) above is used at a temperature range of 200 to 500°C in a plasmaless system.

15 (28) A method for cleaning semiconductor production equipment, comprising use of the cleaning gas described in any one of (11) to (22) above.

(29) The method for cleaning semiconductor production equipment as described in (28) above, wherein  
20 the cleaning gas described in any one of (11) to (22) above is excited to produce plasma and the deposits in the semiconductor production equipment are removed in the plasma.

(30) The method for cleaning semiconductor  
25 production equipment as described in (29) above, wherein the excitation source for the plasma is a microwave

(31) The method for cleaning semiconductor production equipment as described in any one of (28) to (30) above, wherein the cleaning gas described in any one  
30 of (11) to (22) above is used at a temperature range of 50 to 500°C.

(32) The method for cleaning semiconductor

production equipment as described in (28) above, wherein the cleaning gas described in any one of (11) to (22) above is used at a temperature range of 200 to 500°C in a plasmaless system.

5 (33) A method for producing a semiconductor device, comprising a cleaning step of using a cleaning gas containing an inert gas and at least two gases selected from the group consisting of SF<sub>6</sub>, F<sub>2</sub> and NF<sub>3</sub> excluding the combination of F<sub>2</sub> and NF<sub>3</sub> alone, and a decomposition step  
10 of decomposing a fluorocompound-containing gas discharged from the cleaning step.

(34) The method for producing a semiconductor device as described in (33) above, wherein the fluorocompound is at least one compound selected from the group consisting  
15 of HF, SiF<sub>4</sub>, SF<sub>6</sub>, SF<sub>4</sub>, SOF<sub>2</sub>, SO<sub>2</sub>F<sub>2</sub>, and WF<sub>6</sub>.

(35) A method for producing a semiconductor device, comprising a cleaning step of using a cleaning gas containing an inert gas, an oxygen-containing gas and at least two gases selected from the group consisting of SF<sub>6</sub>,  
20 F<sub>2</sub> and NF<sub>3</sub> excluding the combination of F<sub>2</sub> and NF<sub>3</sub> alone, and a decomposition step of decomposing a fluorocompound-containing gas discharged from the cleaning step.

(36) The method for producing a semiconductor device as described in (35) above, wherein the fluorocompound is  
25 at least one compound selected from the group consisting of HF, SiF<sub>4</sub>, SF<sub>6</sub>, SF<sub>4</sub>, SOF<sub>2</sub>, SO<sub>2</sub>F<sub>2</sub>, and WF<sub>6</sub>.

#### BRIEF DESCRIPTION OF DRAWING

30 Fig. 1 is a schematic view of etching equipment using the cleaning gas of the present invention.



## DETAILED DESCRIPTION OF THE INVENTION

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The present invention provides "a cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits in semiconductor production equipment, comprising an inert gas,  $\text{SF}_6$  and one or both of  $\text{F}_2$  and  $\text{NF}_3$ " (the invention of the first cleaning gas), "a cleaning gas for semiconductor production equipment, which is a cleaning gas for removing deposits in semiconductor production equipment, comprising an inert gas, an oxygen-containing gas,  $\text{SF}_6$  and one or both of  $\text{F}_2$  and  $\text{NF}_3$ " (the invention of the second cleaning gas), "a method for cleaning semiconductor production equipment, comprising use of the above-described cleaning gas" and "a method for producing a semiconductor device, comprising a cleaning step of using the above cleaning gas, and a decomposition step of decomposing a fluorocompound-containing gas discharged from the cleaning step".

20 The present invention is described in detail below.

The first cleaning gas for semiconductor production equipment of the present invention comprises an inert gas with any one of the three combinations,

- 25  $\text{SF}_6$  and  $\text{F}_2$ ,  
 $\text{SF}_6$  and  $\text{NF}_3$ , or  
 $\text{SF}_6$ ,  $\text{F}_2$  and  $\text{NF}_3$ .

(Hereinafter, the components other than the inert gas in the cleaning gas is referred to as "active gas".

30 The inert gas is at least one gas selected from the group consisting of He, Ne, Ar, Xe, Kr and  $\text{N}_2$ . Among these, the inert gas is preferably at least one gas selected from the group consisting of He, Ar and  $\text{N}_2$ , because the cleaning gas can exhibit high etching rate

and excellent cost performance.

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The mixing ratio of the gas components in the cleaning gas of the present invention is not particularly limited, however, the ratio of the other gas components (NF<sub>3</sub>, F<sub>2</sub> or NF<sub>3</sub> + F<sub>2</sub>) is usually from 0.01 to 5, preferably from 0.1 to 1.5, and the inert gas is from 0.01 to 500, preferably from 0.1 to 300, more preferably from 0.1 to 30, in terms of the volume ratio assuming that SF<sub>6</sub> in the active gas components is 1. When used in production process of semiconductor production equipment or liquid crystal devices, it is preferable that the gas contains the active gas components in a large amount. However, if these gases are activated moreover in plasma on use, the equipment material in the plasma atmosphere may be damaged. On the other hand, if the amount added is too small, the effect is disadvantageously low. These gases may be mixed inside the semiconductor production equipment or in the pipeline leading to the semiconductor production equipment, or the gases may be previously mixed in a gas cylinder.

In the cleaning gas for semiconductor production equipment of the present invention, when F<sub>2</sub> and/or NF<sub>3</sub> gas capable of dissociating particularly at a low energy level and producing an active species is mixed, the effect brought out surpasses the effect by conventionally used cleaning gas or etching gas, such as CF<sub>4</sub> or C<sub>2</sub>F<sub>6</sub>. The synergistic effect by the mixing is presumed to occur because the active species produced at a low energy level acts on undissociated molecule in a chain-reaction manner and accelerates the dissociation.

The cleaning gas of the present invention may contain at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon,

perfluoroether and hydrofluoroether, in the mixed gas comprising an inert gas,  $\text{SF}_6$  and one or both of  $\text{F}_2$  and  $\text{NF}_3$ . The perfluorocarbon and hydrofluorocarbon each is a compound having from 1 to 4 carbon atoms. Examples of the saturated perfluorocarbon compound include  $\text{CF}_4$ ,  $\text{C}_2\text{F}_6$  and  $\text{C}_3\text{F}_8$ , examples of the unsaturated perfluorocarbon compound include  $\text{C}_2\text{F}_4$ ,  $\text{C}_3\text{F}_6$  and  $\text{C}_4\text{F}_6$ , and examples of the hydrofluorocarbon include  $\text{CHF}_3$  and  $\text{C}_2\text{H}_2\text{F}_4$ . The perfluoroether and hydrofluoroether each is a compound having from 2 to 4 carbon atoms. Examples of the perfluoroether include  $\text{CF}_3\text{OCF}_3$  and  $\text{CF}_3\text{OCF}_2\text{CF}_3$ , and examples of the hydrofluoroether include  $\text{CHF}_2\text{OCHF}_2$  and  $\text{CHF}_2\text{OCH}_2\text{CF}_3$ . The mixing ratio of the gas such as perfluorocarbon is from 0.01 to 1, preferably from 0.01 to 0.5, more preferably from 0.01 to 0.2, in terms of the volume ratio assuming that the mixed gas comprising  $\text{SF}_6$ ,  $\text{F}_2$ ,  $\text{NF}_3$  and an inert gas is 1.

The second cleaning gas for semiconductor production equipment of the present invention comprises an inert gas, an oxygen-containing gas, and any one of the three combinations,

$\text{SF}_6$  and  $\text{F}_2$ ,

$\text{SF}_6$  and  $\text{NF}_3$ , or

$\text{SF}_6$ ,  $\text{F}_2$  and  $\text{NF}_3$ .

(Hereinafter, the components, other than the inert gas and oxygen-containing gas in the cleaning gas, are referred to as "active gas".)

The oxygen-containing gas is at least one selected from the group consisting of  $\text{O}_2$ ,  $\text{O}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{NO}$ ,  $\text{NO}_2$ ,  $\text{CO}$  and  $\text{CO}_2$ . Particularly, it is preferable that the oxygen-containing gas is  $\text{O}_2$  and/or  $\text{N}_2\text{O}$ , so that the etching rate of the cleaning gas is increased and thus the cost-performance is improved.

The inert gas is at least one gas selected from the group consisting of He, Ne, Ar, Xe, Kr and N<sub>2</sub>. Among these, the inert gas is preferably at least one gas selected from the group consisting of He, Ar and N<sub>2</sub>,  
5 because the cleaning gas can exhibit high etching rate and excellent cost performance.

The mixing ratio of the gas components in the cleaning gas of the present invention comprising SF<sub>6</sub> with F<sub>2</sub> and/or NF<sub>3</sub>, an oxygen-containing gas and an inert gas  
10 is not particularly limited. However, the ratio is usually such

that F<sub>2</sub> and/or NF<sub>3</sub> is usually from 0.01 to 5, preferably from 0.1 to 1.5,

that the oxygen-containing gas is from 0.01 to 5, preferably from 0.1 to 1.5, and  
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that the inert gas is from 0.01 to 500, preferably from 0.1 to 300, more preferably from 0.1 to 30, in terms of the volume ratio assuming that SF<sub>6</sub> is 1. When used for cleaning gas of manufacturing semiconductor  
20 production equipment or liquid crystal devices, the oxygen-containing gas, SF<sub>6</sub>, F<sub>2</sub> and NF<sub>3</sub> are active, which are preferably contained in a large amount. However, if these gases are activated moreover in plasma on use, the equipment material in the plasma atmosphere may be  
25 damaged. On the other hand, if the amount added is too small, the effect is disadvantageously low. These gases may be mixed inside the semiconductor production equipment or in the pipeline leading to the semiconductor production equipment, or the gases may be previously  
30 mixed in a gas cylinder.

The cleaning gas of the present invention may contain at least one gas selected from the group consisting of perfluorocarbon, hydrofluorocarbon,

perfluoroether and hydrofluoroether, in the mixed gas comprising an oxygen-containing gas, an inert gas, and SF<sub>6</sub> with F<sub>2</sub> and/or NF<sub>3</sub>. The perfluorocarbon and hydrofluorocarbon each is a compound having from 1 to 4 carbon atoms. Examples of the saturated perfluorocarbon compound include CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub> and C<sub>3</sub>F<sub>8</sub>, examples of the unsaturated perfluorocarbon compound include C<sub>2</sub>F<sub>4</sub>, C<sub>3</sub>F<sub>6</sub> and C<sub>4</sub>F<sub>6</sub>, and examples of the hydrofluorocarbon include CHF<sub>3</sub> and C<sub>2</sub>H<sub>2</sub>F<sub>4</sub>. The perfluoroether and hydrofluoroether each is a compound having from 2 to 4 carbon atoms. Examples of the perfluoroether include CF<sub>3</sub>OCF<sub>3</sub> and CF<sub>3</sub>OCF<sub>2</sub>CF<sub>3</sub>, and examples of the hydrofluoroether include CHF<sub>2</sub>OCHF<sub>2</sub> and CHF<sub>2</sub>OCH<sub>2</sub>CF<sub>3</sub>. The mixing ratio of the gas such as perfluorocarbon is from 0.01 to 1, preferably from 0.01 to 0.5, more preferably from 0.01 to 0.2, in terms of the volume ratio assuming that the mixed gas comprising an oxygen-containing gas, an inert gas, and SF<sub>6</sub> with F<sub>2</sub> and/or NF<sub>3</sub> is 1.

The cleaning gas for semiconductor production equipment according to the present invention, comprising an oxygen-containing gas, an inert gas, and SF<sub>6</sub> with F<sub>2</sub> and/or NF<sub>3</sub>, can exhibit effects superior to those provided by a conventional cleaning gas such as CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub>, by containing

(1) F<sub>2</sub> and/or NF<sub>3</sub>, gas which dissociates at a low energy level and produces an active species, and

(2) oxygen atoms which are effective in producing and maintaining active species.

The effect involved by containing F<sub>2</sub> and/or NF<sub>3</sub> as a component in the mixed gas is presumed to occur because the active species produced at a low energy level acts on undissociated molecule in a chain-reaction manner and

accelerates the dissociation. The effect involved by containing oxygen as a component in the mixed gas is presumed to occur because the oxygen helps maintain activity of active species and prevents deactivation caused by rebinding.

In the case of cleaning semiconductor production equipment using the cleaning gas of the present invention, the gas may be used under the plasma condition or under the plasmaless condition.

When the gas is used under the plasma condition, the excitation source is not particularly limited as long as plasma is excited from the cleaning gas of the present invention, but a microwave excitation source is preferred because good cleaning efficiency can be attained. Also, the temperature and the pressure when the cleaning gas of the present invention is used are not particularly limited as long as plasma can be produced, but the temperature range is preferably from 50 to 500°C and the pressure range is preferably from 1 to 500 Pa.

In the case of plasmaless condition, the cleaning gas is introduced into a chamber, the inner pressure of the chamber is preferably set to 1 to 67 Pa and at least a part of or either one of the inside of chamber and the cleaning gas is heated at 200 to 500°C to generate free fluorine having reactivity from the cleaning gas. Then, deposits are etched and removed from the chamber and from other regions where deposits are accumulated, and thereby the semiconductor production equipment can be cleaned.

Fig. 1 is a view showing one example of the etching equipment using the cleaning gas of the present invention. The cleaning gas is introduced into a chamber 1 set at a constant temperature from a cleaning gas inlet 6 and at

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this time, the gas is excited by a microwave plasma excitation source 4 and produces plasma. The gas obtained after the etching of a silicon wafer 2 on sample stage 3 is discharged by a dry pump 5 and rendered harmless using a decomposing agent according to the kind of the gases contained therein. Furthermore, the deposits accumulated after the etching are efficiently removed by repeating the same operation as the etching, and thereby the chamber can be efficiently cleaned.

10 The method for producing a semiconductor device of the present invention is described below.

As described above, according to the present invention, the cleaning of semiconductor production equipment can be efficiently performed. However, the gas discharged from the cleaning step using the cleaning gas of the present invention contains fluorocompounds such as HF, SiF<sub>4</sub>, SF<sub>4</sub>, SOF<sub>2</sub>, SO<sub>2</sub>F<sub>2</sub> and WF<sub>6</sub>, in addition to SF<sub>6</sub>, F<sub>2</sub> and NF<sub>3</sub> used as the cleaning gas. If these compounds including SF<sub>6</sub>, F<sub>2</sub> and NF<sub>3</sub> are discharged intact into atmosphere, they greatly affect the global warming or generate an acid gas by decomposition, therefore, each compound must be completely rendered harmless. In the method for producing a semiconductor device, the present invention provides a production method of a semiconductor device, comprising a cleaning step of cleaning semiconductor production equipment and a step of decomposing a fluorocompound-containing gas discharged from the cleaning step.

25 The step of cleaning semiconductor production equipment can be efficiently performed by using the method described above. The method for use in the step of decomposing the fluorocompound-containing gas discharged from the cleaning step is not particularly

limited and the decomposing agent can be appropriately selected according to the kind of the compound contained in the exhaust gas. However, hydrogen fluoride,  $\text{SO}_x$  and the like are preferably fixed as a fluoride or a sulfate of metal, and carbon is preferably discharged after completely decomposing it into carbon dioxide.

#### BEST MODE FOR CARRYING OUT THE INVENTION

The present invention is described in greater detail below by referring to the Examples and Comparative Examples, however, the present invention is not limited to these Examples.

#### Examples 1 to 3

A testing apparatus shown in Fig. 1 was adjusted to an apparatus inner pressure of 300 Pa. A cleaning gas having the composition shown in Table 1 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and then introduced into the testing apparatus to etch a silicon wafer placed in the testing apparatus. The etching rate was determined from the loss in volume of the silicon wafer after etching and the results are shown in Table 1.

25

[Table 1]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	$\text{SF}_6$	$\text{F}_2$	He	
1	1	1	200	200
2	1	0.5	170	180
3	1	1.5	250	190



## Examples 4 to 6

A testing apparatus shown in Fig. 1 was adjusted to an apparatus inner pressure of 300 Pa. A cleaning gas having the composition shown in Table 2 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and then introduced into the testing apparatus to etch a silicon wafer placed in the testing apparatus. The etching rate was determined from the loss in volume of the silicon wafer after the etching and the results are shown in Table 2.

[Table 2]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	SF <sub>6</sub>	NF <sub>3</sub>	He	
4	1	1	200	200
5	1	0.5	170	180
6	1	1.5	250	190

15

## Comparative Examples 1 to 5

The etching rate of each cleaning gas was determined in the same manner as in Examples 1 to 6 except that the cleaning gas was changed to a gas having the composition shown in Table 3.

20

[Table 3]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)		Etching Rate (nm/min)
	Gas Used	Mixing Ratio	
1	NF <sub>3</sub> /He	1/100	190
2	SF <sub>6</sub> /He	1/100	70
3	F <sub>2</sub> /He	1/100	170
4	CF <sub>4</sub> /He	1/100	17
5	C <sub>2</sub> F <sub>6</sub> /He	1/100	6

Among the cleaning gases mixed with He shown in Table 3, the etching rate was highest in the case of using NF<sub>3</sub>.

#### Comparative Examples 6 to 8

The etching rate was determined in the same manner as in Examples 1 to 6 except that the cleaning gases were changed to the gases each having the composition shown in Table 4.

[Table 4]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	NF <sub>3</sub>	F <sub>2</sub>	He	
6	1	1	200	175
7	1	0.5	170	170
8	1	1.5	250	170

All of the etching rate of the mixed gases shown in

Comparative Examples 6 to 8 were lower than the rate of the cleaning gases of the present invention shown in Examples 1 to 6.

5 Comparative Examples 9 to 11

The etching rate was determined in the same manner as in Examples 1 to 6 except that the cleaning gases were changed to the gases each having the composition shown in Table 5.

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[Table 5]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	CF <sub>4</sub>	F <sub>2</sub>	He	
9	1	1	200	140
10	1	0.5	170	120
11	1	1.5	250	155

15 All of the etching rate of the mixed gases shown in Comparative Examples 9 to 11 were lower than the rate of the cleaning gases of the present invention shown in Examples 1 to 6.

Comparative Examples 12 to 14

20 The etching rate was determined in the same manner as in Examples 1 to 6 except that the cleaning gases were changed to the gases each having the composition shown in Table 6.

[Table 6]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	C <sub>2</sub> F <sub>6</sub>	F <sub>2</sub>	He	
12	1	1	200	50
13	1	0.5	170	30
14	1	1.5	250	100

5 All of the etching rate of the mixed gases shown in Comparative Examples 12 to 14 were lower than the rate of the cleaning gases of the present invention shown in Examples 1 to 6.

#### Comparative Example 15

10 The etching rate was determined in the same manner as in Examples 1 to 6 except that the cleaning gas was changed to a gas having the composition shown in Table 7.

[Table 7]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)		Etching Rate (nm/min)
	Gas Used	Mixing Ratio	
15	NF <sub>3</sub> /He	1/10	1,900

15 It is seen that when the concentration of NF<sub>3</sub> was increased to ten times that of Comparative Example 1, the etching rate also became ten times higher.

#### Example 7

20 The etching rate of the cleaning gas of the present invention was determined in the same manner as in Examples 1 to 3 except that the cleaning gas was changed

to a gas having the composition shown in Table 8.

[Table 8]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	SF <sub>6</sub>	F <sub>2</sub>	He	
7	1	1	20	2,200

The etching rate of the cleaning gas of the present invention shown in Example 7 was more excellent than the rate of NF<sub>3</sub> shown in Comparative Example 15.

#### Example 8

The etching rate of the cleaning gas of the present invention was determined in the same manner as in Examples 4 to 6 except that the cleaning gas was changed to a gas having the composition shown in Table 9.

[Table 9]

Example	Gas Used and Mixing Ratio (Volume Ratio)			Etching Rate (nm/min)
	SF <sub>6</sub>	NF <sub>3</sub>	He	
8	1	1	20	2,200

The etching rate of the cleaning gas of the present invention shown in Example 8 was more excellent than the rate of NF<sub>3</sub> shown in Comparative Example 15.

#### Examples 9 to 11

A testing apparatus shown in Fig. 1 was adjusted to an apparatus inner pressure of 300 Pa. A cleaning gas having the composition shown in Table 10 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and then introduced into the testing apparatus to etch a

silicon wafer placed in the testing apparatus. The etching rate was determined from the loss in volume of the silicon wafer after the etching and the results are shown in Table 10.

5

[Table 10]

Example	Gas Used and Mixing Ratio (Volume Ratio)				Etching Rate (nm/min)
	SF <sub>6</sub>	F <sub>2</sub>	O <sub>2</sub>	He	
9	1	1	0.5	200	300
10	1	0.5	0.5	170	260
11	1	1.5	0.5	250	290

#### Comparative Example 16 to 18

The etching rate of the cleaning gas of the present invention was determined in the same manner as in Examples 9 to 11 except that the cleaning gas was changed to a gas having the composition shown in Table 11.

[Table 11]

Comparative Example	Gas Used and Mixing Ratio (Volume Ratio)				Etching Rate (nm/min)
	NF <sub>3</sub>	F <sub>2</sub>	O <sub>2</sub>	He	
16	1	1	0.5	200	170
17	1	0.5	0.5	170	160
18	1	1.5	0.5	250	160

15

All of the etching rate of the mixed gases shown in Comparative Examples 16 to 18 were lower than the rate of the cleaning gases of the present invention shown in Examples 9 to 11.

## Example 12

The etching rate of the cleaning gas of the present invention was determined in the same manner as in Examples 9 to 11 except that the cleaning gas was changed to a gas having the composition shown in Table 12.

[Table 12]

Example	Gas Used and Mixing Ratio (Volume Ratio)				Etching Rate (nm/min)
	SF <sub>6</sub>	F <sub>2</sub>	O <sub>2</sub>	He	
12	1	1	0.5	20	3,000

The etching rate of the cleaning gas of the present invention shown in Example 12 was more excellent than the rate of NF<sub>3</sub> shown in Comparative Example 15.

## Example 13

In place of a silicon wafer, a quartz piece having accumulated thereon deposits of amorphous silicon, silicon nitride and the like was used for the cleaning. The cleaning gas used in Example 1 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and introduced into a chamber of a testing apparatus adjusted to an inner pressure of 300 Pa, and the quartz piece was cleaned and then taken out. As a result, it was confirmed that deposits were completely removed.

## Example 14

In place of a silicon wafer, a quartz piece having accumulated thereon deposits of amorphous silicon, silicon nitride and the like was used for the cleaning.

The cleaning gas used in Example 4 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and introduced into a chamber of a testing apparatus adjusted to an inner pressure of 300 Pa, and the quartz piece was cleaned and then taken out. As a result, it was confirmed that deposits were completely removed.

#### Example 15

In place of a silicon wafer, a quartz piece having accumulated thereon deposits of amorphous silicon, silicon nitride and the like was used for the cleaning. The cleaning gas used in Example 9 was excited by a microwave plasma excitation source of 2.45 GHz and 500 W and introduced into a chamber of a testing apparatus adjusted to an inner pressure of 300 Pa, and the quartz piece was cleaned and then taken out. As a result, it was confirmed that deposits were completely removed.

#### INDUSTRIAL APPLICABILITY

The cleaning gas for semiconductor production equipment of the present invention is high in the etching rate, therefore, ensures efficient cleaning and excellent cost performance. According to the method for cleaning semiconductor production equipment of the present invention, unnecessary deposits in the film-forming equipment or etching equipment for the production of a semiconductor or a TFT liquid crystal element accumulated at the film-formation or etching of silicon, silicon nitride, silicon oxide, tungsten or the like can be efficiently removed. Furthermore, by using the method comprising a cleaning step of using the cleaning gas of the present invention and a step of decomposing and thereby rendering harmless the fluorocompound-containing



exhaust gas discharged from the cleaning step, a semiconductor device can be efficiently produced.

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